



**UNIVERSITI PUTRA MALAYSIA**

**GROWTH AND YIELD OF TWO FORAGE LEGUMES OF  
CONTRASTING GROWTH HABITS UNDER SHADE**

**PENSRI SORNPRASITTI.**

**FP 2004 36**

**GROWTH AND YIELD OF TWO FORAGE LEGUMES OF  
CONTRASTING GROWTH HABITS UNDER SHADE**

**By**

**PENSRI SORNPRASITTI**

**Thesis Submitted to the School of Graduate Studies,  
Universiti Putra Malaysia, in Fulfilment of the Requirements for the  
Degree of Doctor of Philosophy**

**November 2004**



## **DEDICATION**

**To my beloved father and mother**

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment  
of the requirements for the degree of Doctor of Philosophy

**GROWTH AND YIELD OF TWO FORAGE LEGUMES OF  
CONTRASTING GROWTH HABITS UNDER SHADE**

**By**

**PENSRI SORNPRASITTI**

**November 2004**

**Chairman : Associate Professor Mohd Ridzwan Abd. Halim, Ph.D.**

**Faculty : Agriculture**

A study was conducted to evaluate the responses of two forage legumes *Arachis pinto* Krapov. & D. Gregory (Arachis) and *Stylosanthes guianensis* (Aublet) Sw. (Stylo), of contrasting growth habits (prostrate and erect type) to levels of shade. Treatments used over three experiments included three radiation regimes (30, 50 and 100% light transmission), two cutting intervals (6 and 8 week), two cutting heights (5 and 10 cm) and the removal of residual leaves on yield and growth of the plants.

Both species had reduced yield with increased shading but Stylo showed greater reduction in yield with shade compared to Arachis. Under full sunlight, Stylo performed better giving a 43 percent greater yield than Arachis. On the other hand, Arachis yielded 6 percent more than Stylo under both shaded treatments, indicating

that the prostrate habit made the plant more tolerant to shading. Arachis also had a greater leaf/stem ratio, and better nodulation under shade than Stylo. The better nodulation of Arachis under shade compared to Stylo may have attributed to the greater shade tolerance of Arachis.

Both legumes were affected by cutting interval; the longer cutting interval of 8 weeks gave higher yield than the 6 weeks cutting interval (increase of 20.7 percent for Arachis and 36.5 percent for Stylo). On the other hand, nutritive quality was better for both legumes with the shorter cutting interval. Increased frequency of cutting reduced plant persistence of Stylo by 8.8 percent while that of Arachis increased by 26 percent, showing that the legumes with the prostrate habit is more tolerant to frequent cutting.

Cutting height had significant effect on yield of Stylo and Arachis under shading, both giving higher yield under 10 cm cutting height than 5 cm cutting height. Stylo showed a greater reduction in yield (40%) than Arachis (17.1%) with the lower cutting height. This proved that the prostrate habit made the plant more tolerant of low cutting height than the upright habit.

The presence of residual leaves was more important for regrowth of Arachis than for Stylo. In Stylo, plant regrowth was influenced by cutting height irrespective of the presence or absence of residual leaves. On the other hand, in Arachis, plants

cut at the low cutting height gave similar regrowth with those at the higher cutting height as long as residual leaves are retained.

In conclusion, the upright legume, Stylo was less tolerant to shading than the prostrate legume Arachis. The latter should be a more suitable legume for use under the integration system where forages are grown under the plantation crops. Arachis is also more tolerant to intensive defoliation as shown by its better ability to withstand shorter cutting interval and lower cutting height than Stylo.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**TUMBESARAN DAN HASIL DUA FORAJ KEKACANG YANG  
BERLAINAN TABIAT TUMBESARAN DI BAWAH NAUNGAN**

**Oleh**

**PENSRI SORNPRASITTI**

**November 2004**

**Pengerusi : Profesor Madya Mohd Ridzwan Abd. Halim, Ph.D.**

**Fakulti : Pertanian**

Satu kajian telah dilaksanakan untuk menilai respons dua kekacang foraj *Arachis pinto* Krapov. & D. Gregory (*Arachis*) and *Stylosanthes guianensis* (Aublet) Sw. (*Stylo*) yang berlainan tabiat tumbuhan (melata dan tegak) terhadap aras naungan. Perlakuan-perlakuan yang digunakan dalam tiga eksperimen termasuk aras radiasi (30, 50 dan 100 % sinaran cahaya), dua selang masa pemotongan (6 dan 8 minggu), dua aras pemotongan (5 dan 10 cm) dan pembuangan baki daun terhadap hasil dan tumbesaran tanaman.

Hasil kedua-dua spesies menurun dengan peningkatan naungan tetapi *Stylo* menunjukkan penurunan hasil yang lebih ketara dari *Arachis*. Di bawah sinaran cahaya penuh, *Stylo* menunjukkan prestasi yang lebih baik dengan hasil 43 peratus lebih tinggi dari *Arachis*. Sebaliknya, *Arachis* mendapat hasil enam peratus lebih

tinggi dari Stylo di bawah kedua-dua perlakuan naungan, menunjukkan tabiat melata membuatkan tumbuhan lebih toleran terhadap naungan. Arachis juga mempunyai nisbah daun/batang dan nodulasi yang lebih tinggi dari Stylo. Keupayaan Arachis membentuk nodul di bawah naungan mungkin menyebabkannya lebih toleran terhadap naungan berbanding Stylo.

Kedua-dua kekacang dipengaruhi oleh selang masa pemotongan; selang masa yang lebih lama, 8 minggu, memberikan hasil yang lebih tinggi dari selang masa 6 minggu (peningkatan 20.7 peratus bagi Arachis dan 36.5 peratus bagi Stylo). Sebaliknya, kualiti pemakanan adalah lebih baik dengan selang masa yang lebih singkat. Peningkatan kekerapan pemotongan juga merendahkan ketahanan Stylo 8.8 peratus manakala ketahanan Arachis meningkat 26 peratus, menunjukkan kekacang tabiat melata lebih toleran terhadap pemotongan kerap.

Aras pemotongan menunjukkan kesan bererti terhadap hasil Stylo dan Arachis di bawah naungan, kedua-dua menunjukkan hasil yang lebih tinggi pada aras pemotongan 10 cm berbanding dengan 5 cm. Stylo menunjukkan penurunan hasil yang lebih ketara (40 peratus) berbanding Arachis (17.1 peratus) dengan aras pemotongan rendah. Ini membuktikan tabiat melata membuatkan tumbuhan lebih toleran terhadap pemotongan rendah.

Kehadiran daun-daun baki adalah lebih penting untuk tumbesaran semula Arachis daripada tumbesaran semula Stylo. Bagi Stylo, tumbesaran semula dipengaruhi



oleh aras pemotongan sama ada daun baki dibuang atau tidak. Sebaliknya, bagi *Arachis*, tumbuhan yang dipotong rendah dapat tumbuh semula dengan kadar yang sama dengan yang dipotong tinggi selagi daun baki tidak dibuang.

Kesimpulannya, kekacang jenis tegak, *Stylo*, adalah kurang toleransi terhadap naungan berbanding dengan kekacang melata *Arachis*. *Arachis* lebih sesuai digunakan sebagai kekacang untuk ditanam di bawah sistem integrasi yang melibatkan penanaman foraj di bawah tanaman perladangan. *Arachis* juga lebih toleran terhadap defoliasi intensif berbanding *Stylo*, seperti yang ditunjukkan dari keupayaannya untuk bertahan di bawah pemotongan yang kerap dan aras pemotongan yang rendah.

## **ACKNOWLEDGEMENTS**

I would like to express my profound gratitude to Assoc. Prof. Dr. Mohd Ridzwan Abd. Halim, Chairman of the Supervisory Committee for his constant guidance, suggestions and encouragement throughout the preparation of this thesis. I am highly indebted to Prof. Dr. Zainal Aznam Mohd Jelani and Prof. Dr. Abd. Razak Alimon, members of my Supervisory Committee for their guidance, suggestions and comments.

I take this opportunity to express my thanks to Mr. Mohd Sharil Ab. Rahman, Mr. Zahardin Zulkifli, Mr. Abidin Md Isa, Mr. Asare Daud, Mr. Mazlan Bangi, Mr. Azahar Othman and Mr. Baharin Mohd Amin for their help in the field work. Thanks are also extended to Mrs. Zarinah Mohd. Basir, Mr. Ibrahim Mohsin, Mr. Saparin Demin, Mr. Khoiri Kandar, Mr. Abd. Aziz Ismail, Mr. Bhanu Achan, Mrs. Salmi Yaacob, Mr. Ariffin Abu Hassan and Mr. Mokhtar Mustapar for their help in the laboratory work.

I am thankful to the Department of Livestock Development, Thailand for granting the study leave for me to pursue my Ph.D. study. The financial supports from Universiti Putra Malaysia through the project 01-02-04-0199/51159 (Production of Fodder Grasses and Legumes in Intensive Ruminant Production Systems) of Intensified Research in Priority Areas (IRPA) grant and the Forage Working Group Funds are highly appreciated.



My sincere appreciation goes to Mr. Chen Chin Peng, Dr. Wong Choi Chee, my brother and sisters who have given me moral support and encouragement throughout my study in Malaysia. Finally, I would like to thank the Almighty for giving me a chance to undertake this study.

I certify that an Examination Committee met on 3<sup>rd</sup> November 2004 to conduct the final examination of Pensri Sornprasitti on her Doctor of Philosophy thesis entitled “Growth and Yield of Two Forage Legumes of Contrasting Growth Habits under Shade” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

**ABDUL RANI BAHAMAN, Ph.D.**

Professor  
Faculty of Veterinary Medicine  
Universiti Putra Malaysia  
(Chairman)

**MOHD RAZI ISMAIL, Ph.D.**

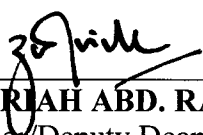
Associate Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Member)

**LIANG JUAN BOO, Ph.D.**

Associate Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Member)

**LYNN E. SOLLENBERGER, Ph.D.**

Professor  
Institute of Food and Agricultural Sciences  
University of Florida  
(Independent Examiner)

---

**ZAKARIAH ABD. RASHID, Ph.D.**  
Professor/Deputy Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 20 DEC 2004



This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

**MOHD RIDZWAN ABD. HALIM, Ph.D.**

Associate Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Chairman)

**ZAINAL AZNAM MOHD JELAN, Ph.D.**

Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Member)

**ABD. RAZAK ALIMON, Ph.D.**

Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Member)



---

**AINI IDERIS, Ph.D.**

Professor/Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 13 JAN 2005

## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

Pensri Sornprasitti

**PENSRI SORNPRASITTI**

Date: 31-12-2024

## TABLE OF CONTENTS

	<b>Page</b>
<b>DEDICATION</b>	ii
<b>ABSTRACT</b>	iii
<b>ABSTRAK</b>	vi
<b>ACKNOWLEDGEMENTS</b>	ix
<b>APPROVAL</b>	xi
<b>DECLARATION</b>	xiii
<b>LIST OF TABLES</b>	xvii
<b>LIST OF FIGURES</b>	xx
<b>LIST OF PLATES</b>	xxiii
 <b>CHAPTER</b>	
 <b>I INTRODUCTION</b>	 1
 <b>II LITERATURE REVIEW</b>	 7
Photosynthesis of Plants	7
Photosynthesis Rate in Tropical Legumes	8
Photosynthesis and Light Intensities	9
Effect of Shade on the Morphology and Growth Habit	12
Screening of Shade Tolerant Forages for Plantations	15
Grasses	15
Legumes	17
Quantity and Quality of the Existing Forage Plants under Plantation Crops	18
Natural Forage Species under Plantation Crops	18
Forage Yield under Oil Palm Plantations	20
Forage Yield under Rubber and Coconut Tree Plantations	21
Introduction of Improved Forage Plants under Plantation Crops	21
Advantages of Integration of Livestock in Plantation Crops	22
Regrowth of Plant Following Defoliation	22
The Responses at the Immediate Point of Defoliation	24
Plant Growth Response Following Defoliation	27
Recovery Processes after Defoliation	28
Production and Defoliation of Forages under Shade and Unshaded Conditions and Plant Growth Characteristics	29
Plant Biomass	32
Plant Persistence	34
Plant Nutrient Content	35



	Botanical and Agronomic Characteristics of Two Tropical Legumes	37
	<i>Arachis pinto</i> Krapov. & D. Gregory	37
	<i>Stylosanthes guianensis</i> (Aublet) Sw.	41
	Nutrient Content of <i>Arachis</i> and <i>Stylo</i>	44
<b>III</b>	<b>EXPERIMENT 1: YIELD AND PERSISTENCE OF TWO LEGUMES UNDER DIFFERENT LEVELS OF SHADE AND CUTTING INTERVALS</b>	46
	Materials and Methods	46
	Location of the Experiment	46
	Experimental Design	47
	Management Practices	47
	Environmental Conditions	49
	Plant Measurements	53
	Data Analysis	57
	Results and Discussion	58
	Yield Parameters, Persistence and Nodules	58
	Nutrient Content	79
	Growth Parameters	90
	Photosynthesis Rate and Stomata Conductance	99
	Conclusion	102
<b>IV</b>	<b>EXPERIMENT 2: EFFECT OF TWO CUTTING HEIGHTS ON REGROWTH OF TWO LEGUMES GROWN UNDER DIFFERENT LEVELS OF SHADE</b>	105
	Materials and Methods	105
	Location of the Experiment	105
	Experimental Design	106
	Management Practices	106
	Environmental Conditions	108
	Plant Measurement	108
	Data Analysis	112
	Results and Discussion	112
	Yield Parameters	112
	Nutrient Content	117
	Growth Parameters	119
	Photosynthesis Rate and Stomata Conductance	124
	Conclusion	125
<b>V</b>	<b>EXPERIMENT 3: EFFECT OF REMOVAL OF RESIDUAL LEAVES ON REGROWTH OF TWO LEGUMES</b>	126
	Materials and Methods	127
	Location of the Experiment	127
	Experimental Design	127





Management Practices	128
Environmental Conditions	128
Plant Measurements	128
Data Analysis	132
Results and Discussion	133
Yield Parameters	133
Relative Growth Rate	146
Relative Leaf Growth Rate	149
Relative Stem Growth Rate	150
Relative Root Growth Rate	151
Net Assimilation Rate	153
Light Interception	153
Conclusion	156
<b>VI GENERAL DISCUSSION AND CONCLUSION</b>	<b>157</b>
<b>BIBLIOGRAPHY</b>	<b>162</b>
<b>APPENDICES</b>	<b>181</b>
<b>BIODATA OF THE AUTHOR</b>	<b>221</b>



## LIST OF TABLES

Table	Page
2.1 Shade tolerant grass species	16
2.2 Shade tolerance of some grass species	16
2.3 Shade tolerance of some legume species	17
2.4 Yield (kg ha <sup>-1</sup> ) of legumes under artificial shade	33
2.5 Biomass yield of different types of shade tolerant legume species	34
2.6 Nitrogen content (%) of legume under artificial shade	36
2.7 Agronomic performance of <i>Stylosanthes guianensis</i> CIAT 184	43
3.1 Harvest schedule in Experiment 1	54
3.2 Yield characteristics of Arachis and Stylo	59
3.3 Nutrient content of legumes under shade and cutting intervals	80
3.4 Leaf photosynthesis rate and stomata conductance	101
4.1 Harvest schedule in Experiment 2	110
4.2 Effect of treatments on yield parameters	113
4.3 Effect of treatments on nutrient content	118
4.4 Effect of treatments on some growth characteristics at Harvest 2	120
4.5 Effect of treatments on physiological characteristics	124
5.1 Harvest schedule in Experiment 3	130
5.2 Effect of treatments on relative growth rate	148
5.3 Effect of treatments on relative leaf growth rate	149
5.4 Effect of treatments on relative stem growth rate	151
5.5 Effect of treatments on relative root growth rate	152
5.6 Effect of treatments on net assimilation rate	154



<b>Table</b>	<b>Page</b>
A.1 Effect of treatments on yield parameters at Harvest 1 of the 6-week cutting interval	182
A.2 Effect of treatments on yield parameters at Harvest 2 of the 6-week cutting interval	183
A.3 Effect of treatments on yield parameters at Harvest 3 of the 6-week cutting interval	184
A.4 Effect of treatments on yield parameters at Harvest 4 of the 6-week cutting interval	185
A.5 Effect of treatments on yield parameters at Harvest 1 of the 8-week cutting interval	186
A.6 Effect of treatments on yield parameters at Harvest 2 of the 8-week cutting interval	187
A.7 Effect of treatments on yield parameters at Harvest 3 of the 8-week cutting interval	188
A.8 Effect of treatments on yield parameters of legumes at Harvest 1 of Experiment 2	189
A.9 Effect of treatments on yield parameters of legumes at Harvest 2 of Experiment 2	190
A.10 Effect of treatments on yield parameters of legumes at Harvest 3 of Experiment 2	191
A.11 Effect of treatments at different regrowth periods	192
B.1 ANOVA table for effect of treatments on yield characteristics in Experiment 1	196
B.2 ANOVA table for effect of treatments on nutrient content	198
B.3 ANOVA table for effect of treatments on yield parameter and nutrient content at harvest 1 of the 6-week cutting interval	199
B.4 ANOVA table for effect of treatments on yield parameter and nutrient content at Harvest 2 of the 6-week cutting interval	200
B.5 ANOVA table for effect of treatments on yield parameter and nutrient content at Harvest 3 of the 6-week cutting interval	201
B.6 ANOVA table for effect of treatments on yield parameter and nutrient content at Harvest 4 of the 6-week cutting interval	202
B.7 ANOVA table for effect of treatments on yield parameter and nutrient content at Harvest 1 of the 8-week cutting interval	203

<b>Table</b>	<b>Page</b>
B.8 ANOVA table for effect of treatments on yield parameter and nutrient content at Harvest 2 of the 8-week cutting interval	204
B.9 ANOVA table for effect of treatment on yield parameter and nutrient content at Harvest 3 of the 8-week cutting interval	205
B.10 ANOVA table of effect of treatments on yield parameters of Experiment 2	206
B.11 ANOVA table of effect of treatments on yield parameters of Harvest 1 of Experiment 2	207
B.12 ANOVA table of effect of treatments on yield parameters of Harvest 2 of Experiment 2	208
B.13 ANOVA table of effect of treatments on yield parameters of Harvest 3 of Experiment 2	209
B.14 ANOVA for effect of treatments on yield parameters at 1 week regrowth	210
B.15 ANOVA for effect of treatments on yield parameters at 2 week regrowth	211
B.16 ANOVA for effect of treatments on yield parameters at 3 week regrowth	212
B.17 ANOVA for effect of treatments on yield parameters at 4 week regrowth	213
B.18 ANOVA for effect of treatments on yield parameters at 5 week regrowth	214
B.19 ANOVA for effect of treatments on yield parameters at 6 week regrowth	215
B.20 ANOVA for treatments on relative growth rate	216
B.21 ANOVA for treatments on relative leaf growth rate	217
B.22 ANOVA for treatments on relative stem growth rate	218
B.23 ANOVA for treatments on relative root growth rate	219
B.24 ANOVA for treatments on net assimilation rate	220

## LIST OF FIGURES

Figure	Page
2.1 The Effect of Light Intensity on Photosynthesis	9
2.2 Total Soluble Carbohydrate Content of i) Tops and ii) Root of Cockfoot Subjected to Lamina Removal at Two Day Intervals	27
3.1 Size of Shade Frame in Experiment 1	51
3.2 Weekly Weather Data of Experiment 1	52
3.3 Photosynthetically Active Radiation (PAR) in Different Light Transmission from 0800 Hour to 1700 Hour on 13 <sup>th</sup> June 1996	53
3.4 Interaction between Species and Shade on Dry Matter Yield	61
3.5 Interaction between Species and Cutting Interval on Stem Dry Matter Yield	64
3.6 Interaction between Species and Cutting Interval on Total Dry Matter Yield	64
3.7 Linear Regression of Total Shoot Dry Matter Yield of Arachis(A) and Stylo (S) in Two Cutting Intervals (6 and 8 weeks) on Three Light Transmission	65
3.8 Interaction between Species and Light Transmission on Leaf/Stem Ratio	66
3.9 Interaction between Species and Light Transmission on Shoot/Root Ratio	67
3.10 Interaction between Species and Light Transmission on Leaf Area	69
3.11 Interaction between Cutting Interval and Light Transmission on Leaf Area Ratio	70
3.12 Interaction between Species and Light Transmission on Leaf Area Ratio	70
3.13 Interaction between Species and Light Transmission on Leaf Weight Ratio	72
3.14 Interaction between Species and Cutting Interval on Leaf Weight Ratio	72
3.15 Interaction between Species and Light Transmission on Specific Leaf Area	73

<b>Figure</b>		<b>Page</b>
3.16	Interaction between Species and Cutting Interval on Persistence	74
3.17	Interaction between Cutting Interval and Light Transmission on Number of Nodules	77
3.18	Interaction between of Species and Light Transmission on Number of Nodules	77
3.19	Interaction between Cutting Interval and Light Transmission on Nodules Dry Weight	78
3.20	Interaction between Species and Light Transmission on Nodules Dry Weight	78
3.21	Interaction between Species and Cutting Interval on Neutral Detergent Fibre Concentration in leaves	82
3.22	Interaction between Species and Light Transmission on Neutral Detergent Fibre Concentration in Stem	82
3.23	Interaction between Species and Cutting Interval on Neutral Detergent Fibre Concentration in Stem	83
3.24	Interaction between Species and Light Transmission on Acid Detergent Fibre Concentration in Leaves	84
3.25	Interaction between Species and Cutting Interval on Acid Detergent Fibre Concentration in leaves	84
3.26	Interaction between Species and Light Transmission on Acid Detergent Fibre Concentration in Stem	85
3.27	Interaction between Species and Cutting Interval on Acid Detergent Fibre Concentration in Stem	85
3.28	Interaction between Species and Cutting Interval on Nitrogen Concentration in Stem	88
3.29	Interaction between Species and Cutting Interval on Phosphorus Concentration in Leaves	89
3.30	Interaction between Species and Cutting Interval on Phosphorus Concentration in Stem	89
3.31	Leaf Area Index of after Harvest 1	91
3.32	Mean Length of Stem over Experimental Period	93
3.33	Mean Number of Leaves over Experimental Period	95
3.34	Mean Number of Branches over Experimental Period	96

<b>Figure</b>		<b>Page</b>
3.35	Mean Number of Nodes over Experimental Period	98
4.1	Weekly Weather Data during Experiment 2 and Experiment 3	109
4.2	Interaction between Species and Cutting Height on Leaf Dry Matter Yield	115
4.3	Interaction between Species and Cutting Height on Stem Dry Matter Yield	116
4.4	Interaction between Species and Cutting Height on Total Dry Matter Yield	116
4.5	Interaction between Species and Cutting Height on Stem Weight Ratio	117
4.6	Interaction between Species and Cutting Height on Height	121
4.7	Interaction between Light Transmission and Species on Number of Nodules	122
4.8	Interaction between Species and Cutting Height on Number of Nodules	123
4.9	Interaction between Light Transmission and Species on Weight of Nodules	123
5.1	Effect of Residual Leaves on Dry Matter Yield of Legumes	134
5.2	Effect of Residual Leaves on Growth Parameters of Legumes	135
5.3	Leaf Dry Matter Yield of Legumes at Different Age of Regrowth	137
5.4	Stem Dry Matter Yield of Legumes at Different Age of Regrowth	139
5.5	Root Dry Matter Yield of Legumes at Different Age of Regrowth	140
5.6	Total Dry Matter Yield of Legumes at Different Age of Regrowth	142
5.7	Leaf/Stem Ratio of Legumes at Different Age of Regrowth	144
5.8	Shoot/root Ratio of Legumes at Different Age of Regrowth	145
5.9	Leaf Area of Legumes at Different Age of Regrowth	147
5.10	Light Interception of Legumes over Six Weeks Regrowth Period	155

## LIST OF PLATES

Plate		Page
2.1	<i>Arachis pinto</i>	38
2.2	<i>Stylosanthes guianensis</i>	38
3.1	The Arrangement of Pots of Arachis and Stylo	50
3.2	A General View of Experiment 1	50
5.1	Legumes in Pot at First Day of Experiment 3	129
5.2	Legumes at Fifth Weeks of Regrowth	136



## **CHAPTER I**

### **INTRODUCTION**

In Southeast Asian countries, plantation agriculture is an important form of utilisation of land. In Malaysia, for example, more than three million hectares of land are under major plantation crop production (e.g., oil palm, rubber, coconut, and fruit orchard). The plantation area is increasing especially for oil palm (Tajuddin and Wan Zahari, 1992; Department of Agriculture, 2003).

Livestock integration with plantation crops offers great advantage because the forage plants between the plant rows provides extensive grazing for ruminants. Ruminants also help in weed control in the plantations, and increase land use efficiency by reducing the weeding cost from 18 to 38% compared to the use of herbicides and human labour (Tajuddin and Chong, 1994). Thus livestock production under plantation crops has become a popular system. Integration of ruminant livestock in plantations has been reported to be successful with cattle (Dahlan, 1989; Chen, 1992); sheep (Rajion et al., 1994; Haji Baba et al., 1998); goat (Haji Baba et al., 1998), and buffalo (Nordin and Abdullah Sani, 1996; Jayatileka et al., 1998).

Oil palm, rubber, and coconut are normally planted at wide row spacing. During the early establishment of these plants (up to 5 years), the interrow-spaces are